Large Gantry Table for the 10th Generation LCD Substrates

Katsuyoshi SUZUKI*
Naoshi SUZUKI*

NTN has deeply cultivated precision positioning technology and applied it to various types of positioning systems. One of their major fields of application is LCD manufacturing equipment, and **NTN** provides large, long-stroke XY tables suitable for various types of equipment, including **NTN** LCD repair systems.

This paper describes problems arising from the growing size of XY tables and gives an outline of a prototype gantry-type XY table that meets the upcoming super-sized (about 3-m^2 G10) glass substrates.

1. Foreword

The demands for flat panel displays, typically flat-screen television sets, have been increasing at a rapid pace. To address this trend, flat panel manufacturers have been making investments for production of displays that are capable of providing images of higher definition and quality, by adoption of larger sized glass substrate in order to improve production efficiency and enhance value of display products. In this context, longer stroke and higher precision are needed for XY tables that constitute the core of equipment for manufacturing and inspecting LCD substrate.

NTN has been improving and enhancing its XY table products through lighter, larger more rigid designs, and has been incorporating its improved XY tables into LCD repair equipment, color filter repair equipment and plasma display repair equipment. Building upon this accumulated experience, **NTN** has also been actively developing large-sized tables. We have recently developed a large XY table to be able to handle the generation 10 LCD mother glass substrate (the world's largest size). This paper hereunder describes the engineering challenges, and the results of the technical evaluation for this product.

2. History of upsizing of LCD glass substrate

As the applications of LCD expand from personal computers to television sets, the need for larger screens continues to increase rapidly. To cope with this trend, facilities and technologies for producing LCD panels have been improving. Consequently, the size of LCD mother glass substrate has been dramatically increasing.

Table 1 summarizes history of upsizing of LCD glass substrate sizes. The generation 10 mother glass, whose production has started recently, measures about 3,000 mm in one side. The stroke of an XY table, on which such large LCD mother glass substrate is subjected to processing such as laser cut, must also exceed 3,000 mm, and the size of the table needs to be accordingly as large.

Table 1 LCD mother glass size

Generation 2	270×360mm	(1987)
Generation 3	360×465mm	(1994)
Generation 4	550×650mm	(1997)
Generation 5	680×880mm	(2000)
Generation 6	1100×1250mm	(2002)
Generation 7	1500×1800mm	(2004)
Generation 8	1870×2200mm	(2005)
Generation 9	2160×2460mm	(2006)
Generation 10	2850×3050mm	(2009)

*Actual year of realization may differ with a given LCD panel manufacturer.

*Product Engineering Department Precision Equipment Division

3. Restrictions about upsizing of table

So far, in response to the need for handling larger glass substrate, LCD panel manufacturers have been achieving compact table structure by optimizing the shape of the base on an XY table, and improving layout for the linear guide, linear motor, and cable chain. This achievement helps reduce the necessary floor area of the XY table in a clean room and contributes to prevention of occurrence of problems in manufacture and transportation of XY table. In the case of the tables capable of handling generation 10 LCD glass substrate, the minimum table width exceeds 3,500 mm. Consequently, the following two problems have to be addressed:

1) Problem arising from allowable work piece size for machine tool

A relatively high number of machine tools can machine work pieces whose width measures less than 3,000 mm. In contrast, a smaller number of machine tools are capable of processing work pieces with width over 3,000 mm, and machine tool users may fail to satisfy the customer's request for lead time.

2) Problem about maximum allowable dimensions for transportation

With respect to transportation, a larger XY table poses a problem. A relevant law or regulation in Japan (Law of Road Transport Vehicles etc.) stipulates that land transportation with an ordinary vehicle is not permitted if the cargo width exceeds 3,500 mm. A transportation agent may acquire special road occupation permission from a relevant authority and transport the large XY table on a public road during night time. If the machine is fabricated in a sea-side plant, it can be transported on a maritime vessel. Considering these additional requirements, an XY table capable of handling work pieces exceeding 3,500 mm in width poses a large challenge in fulfilling requirements for shorter lead time, and timely fabrication and delivery.

4. Considerations about split structure

The above-mentioned problems can be solved by adopting a split-structured design for the base of XY table. Because dimensions of individual units are smaller, and the scope of available machine tools is greater, engineering considerations about the shape and precision of work piece can be less demanding. At the same time, considerations about limitations with transportation are not necessary.

In developing a block structure, certain requirements need to be satisfied. The structure must feature a design that excels in restoration of accuracy after transportation as separate units, and the machine must be able to be quickly reassembled and adjusted at the site where the machine is installed. More specifically, the block structure must clear the following issues:

① Accuracy of parts mounting surfaces and joint faces

The mounting surfaces on the base for mounting the linear guide, linear scale, linear motor, etc. are important factors that determine the characteristics of XY table. Therefore, higher levels of precision in flatness, straightness, etc. must be satisfied.

When a plurality of bases are assembled into one entity, accuracy of table operation can be jeopardized or the effective life of the linear guide can become shorter if the joints have a problem such as height difference or bend. To avoid this problem, machining precision for each mounting surface needs to be improved, and at the same time, incorporation of an adjusting mechanism will be necessary.

② Easy disassembly, reassembly and adjustment

To help simplify disassembly before shipment, and reassembly and adjustment after delivery at site, the XY table has to consist of a minimum number of components. The XY table needs to be designed such that the functional units mounted can be removed in the form of single block. Additionally the XY table must allow handling with accessible equipment, such as hydraulic jack, through adoption of light-weight, highly rigid members.

③ Accuracy measurement at site

After joining and reassembly of the base, it is necessary to confirm restoration of accuracy of the base. Note, however, the utilities including electric power supply and compressed air may not yet be available at site. Therefore, a simple accuracy confirmation method has to be established in advance.

5. Specifications of super-large table

Table 2 summarizes the specifications of the **NTN** gantry table that is capable of generation 10 (G10) LCD glass substrate, and **Fig. 1** shows appearance of the gantry table.

The Y-axis base can be split into two pieces at its near-middle location, with the line of separation being parallel with the X-axis gantry beam. Therefore, the location of the base joint coincides with the location of the linear guide joint (**Fig. 2**).

Because of availability and reasonable cost, can structures have been adopted for the base and beam, each a major member of the XY table.

Compared with stone material, steel material boasts

higher rigidity and this feature helps achieve a lighter structure in spite of somewhat inferior vibration damping quality. Steel material also features higher degree of freedom in a shape-forming process. In designing the base and beam, **NTN** has attempted to realize simplicity and restoration of accuracy in disassembly and reassembly work while addressing technical challenges associated with disassembly and reassembly procedure.

Table 2 Specification of table for G10 LCD glass substrate

Table specifications	X-axis	Y-axis
Stroke	3,200mm	3,650mm
Max. velocity	1,500mm/s	1,500mm/s
Max. deceleration/acceleration	0.3G	0.3G
Resolution	0.1 μm/pulse	0.1 μm/pulse
Positioning accuracy	30 μm	30 μm
Repeated positioning accuracy	±0.5 μm	±0.5 μm
Horizontal straightness	40 μm	40 μm
Vertical straightness	20 μm	20 μm
Linear motor	Coreless	Cored
Linear scale	Permanently glued	Removable
Gantry constitution	Upper axis beam	Lower axis base
Splitting	None	Two pieces
Material	Steel (can structure)	
External dimensions	W3,900×D5,200×H2,500 mm	
Total mass	15,000 kg	

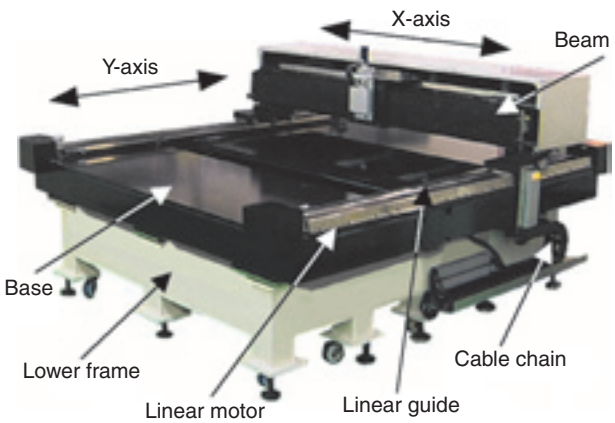

Fig. 1 Appearance of the super-sized table

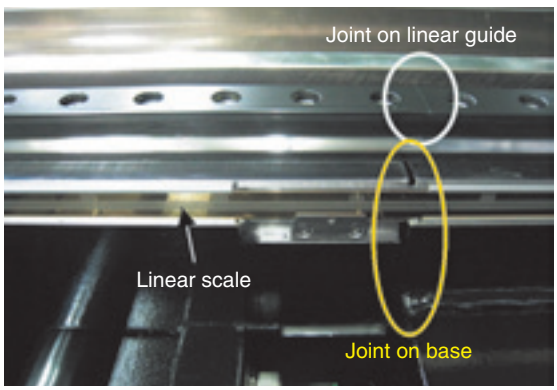

Fig. 2 Division part of the Y-axis base

Upsizing of the LCD glass substrate is intended for improved productivity. A longer process time in proportion with the glass substrate size cannot be justified. Therefore, the table must be faster. The table speed has been increased to 1,500 mm/s by improving thrust for the linear motor and incorporating a lighter table design. Additionally, these enhancements have realized acceleration/deceleration rates of 0.3 G with the table (ability to accelerate to 1,500 mm/s in approximately 0.5 sec.).

To ensure easy disassembly and reassembly of the table, a detachable linear scale that boasts good workability and reliable restoration for mounting accuracy has been selected.

The drivers to be used in conjunction with the linear motors are types featuring high-speed response, helping achieve improved resolution for scale signals: this feature leads to improved controllability that helps inhibit speed variation.

High performance linear motors have been incorporated into the drive system of the gantry table to cope with the longer stroke and higher speed with the larger XY table. A high thrust cored linear motor (**Fig. 3**) has been adopted for the Y-axis to be able to drive the heavy gantry beam with sufficient acceleration, and a coreless linear motor (**Fig. 4**) featuring smaller space and constant speed has been adopted for the X-axis.

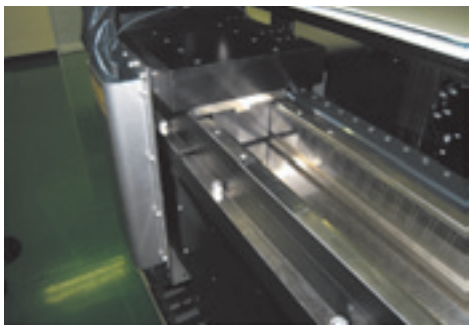

Fig. 3 Linear Servomotor with iron core

Fig. 4 Coreless Linear Servomotor

6. Evaluation test

A sample temporarily assembled (state before disassembly) and another sample in disassembled state were transported on a truck for about 10 km. Then, the samples were reassembled and adjusted. Next, these samples were compared with each other in terms of resultant positioning accuracy, repeated positioning accuracy, and horizontal/vertical straightness in order to confirm effect of reassembly on original accuracy.

As summarized in **Table 3**, we have been able to confirm restoration of accuracy to the specified levels after the Y-axis base was disassembled and reassembled. It has also been verified that disassembly/reassembly is completed in the expected time span.

Fig. 5 plots the difference in actual measurement of positioning accuracy with Y-axis between before and after disassembly of the Y-axis base. Similarly, **Fig. 6** plots the difference in terms of horizontal straightness.

Before the evaluation test, the impact of vibration and installation site factors (such as floor structure) on the performance of the **NTN** gantry table were unknown. In the present evaluation, our gantry table has not exhibited any adverse effects on various accuracy criteria including static accuracy, positioning accuracy, and straightness. In order to fully develop XY table performance, a vibration damping mechanism will be needed which can inhibit transmission of floor vibration to the XY table and promptly dampen residual vibration occurring from transportation of a heavy object. Various vibration damping units and combinations are available, including vibration damping rubber material, vibration damping damper, passive vibration isolation table, and active vibration isolation table. To support a greater table mass, it is necessary to select vibration isolating parts that are resilient, boasting larger load carrying capacity and higher performance. As an XY table manufacturer, **NTN** will address difficult challenges as to optimum selection and proposal of an XY table type that best suits the intended application and performance requirement, while satisfying the cost-performance need.

Table 3 Result of evaluation test (Y-axis)

Evaluation criteria	Variation after reassembly
Positioning accuracy	5.0 μm max.
Repeated positioning accuracy	0.1 μm max.
Horizontal straightness	7.0 μm max.
Vertical straightness	0.1 μm max.

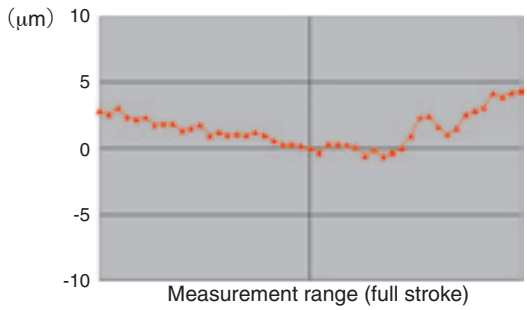

Fig. 5 Difference of positioning accuracy (Y-axis) before and after disassembly and transportation

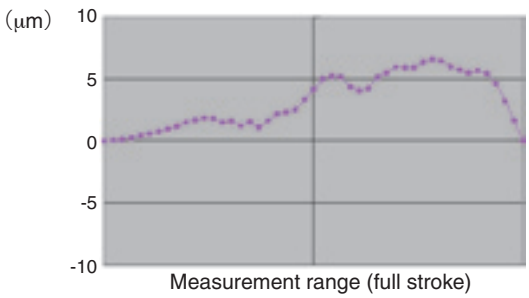

Fig. 6 Difference of horizontal straightness (Y-axis) before and after disassembly and transportation

7. Conclusion

Performance of a large XY table directly governs the performance of LCD manufacturing equipment. In the context of upsizing and achieving higher precision with LCD glass substrate, the requirements have been increasingly complex for the XY table used in LCD manufacturing equipment, and such complex requirements include shape, functions, controllability, and performance.

Based on its accumulated technologies and experiences, **NTN** will address the challenges at higher levels for development, including higher precision, higher speed, and enhanced performance. **NTN** as an XY table manufacturer, will further remain committed to improve productivity and quality of flat panel displays.

References

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Photo of authors

Katsuyoshi SUZUKI
Product Engineering Department
Precision Equipment Division

Naoshi SUZUKI
Product Engineering Department
Precision Equipment Division